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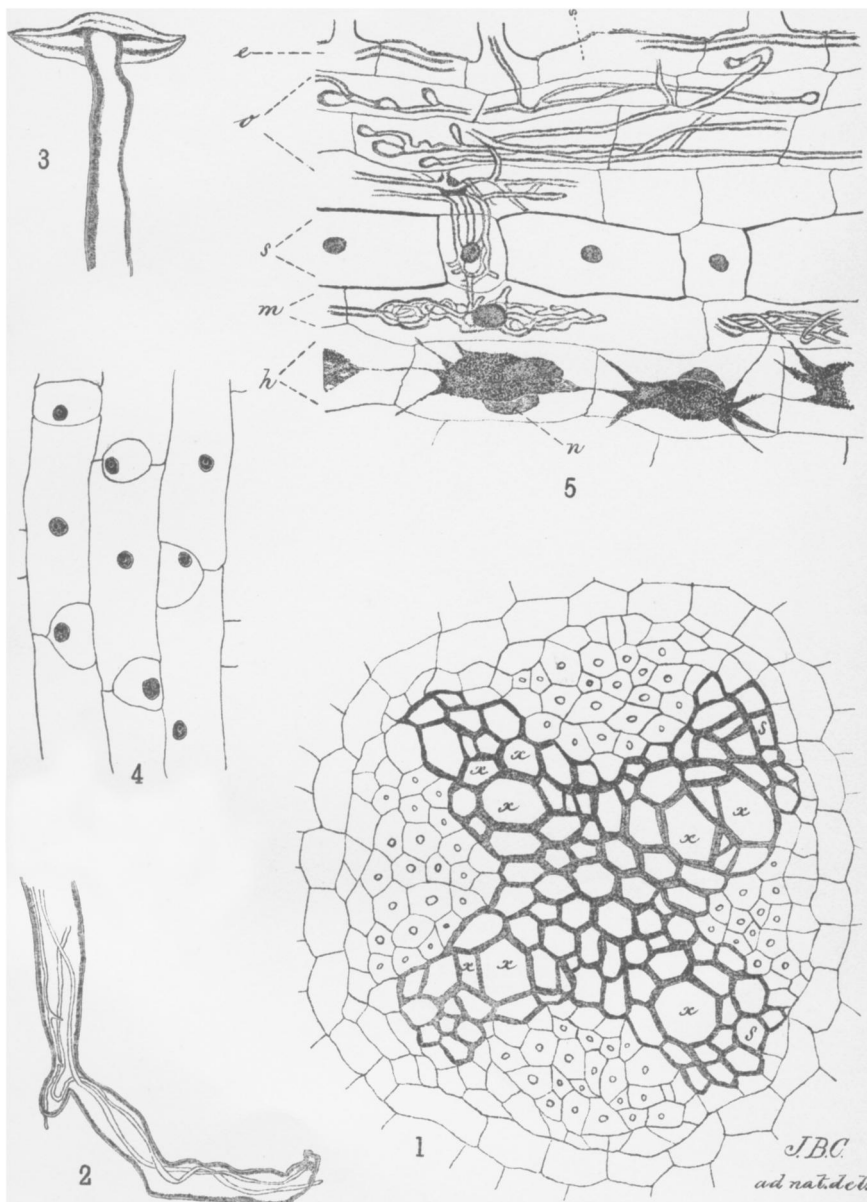
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CLIFFORD ON TIPULARIA UNIFOLIA.

The Mycorhiza of *Tipularia unifolia**

BY JULIA B. CLIFFORD

(PLATE 372)

The writer of this paper undertook a study of the anatomical and physiological relations of *Tipularia* and its symbiotic fungus, for the purpose of extending information on mycorrhizal adaptations, and thus affording a wider basis for the determination of the actual relation between plants associated in this manner.

The material examined consisted of a number of living specimens from South Carolina, which were grown in the greenhouse of the University of Minnesota. The plant consists of an irregular solid corm which sends out an offset in midsummer, from which is formed a daughter corm, giving rise to a single ovate leaf in the autumn which survives the winter. In the spring the leaf dies away and the corm sends up a scape 49 to 50 centimeters high, bearing a raceme of greenish flowers. The roots are few in number, fibrous, and depend from the base of the corm.

STRUCTURE OF THE ROOTS

The Stele.—The stele is tetrarch, well developed, and fairly large for the size of the root, each bundle consists chiefly of two or three large scalariform ducts and a number of spiral vessels. Alternating with the bundles are groups of twelve to twenty sclerenchymatous fibers in which the lumen is almost obliterated. The pericycle is interrupted, and its elements are quite irregular in mature organs. The endodermal cells are large, uneven in size, the lateral walls are sometimes thickened, and all are suberized.

The Cortex.—External to the stele is a region of the cortex consisting of four to six layers of short cylindrical cells, with small intercellular spaces, and thin cellulose walls. These cells contain large fungal vesicles in contact with the nuclei and those of neighboring elements may be seen to be connected by hyphal

*The work described in this paper was done in the physiological laboratory of the University of Minnesota, under the direction of Professor D. T. MacDougal of the New York Botanical Gardens, who also revised the manuscript.

threads. In many instances the vesicles almost fill the cells. They stain a yellowish brown with Bismark brown and alcohol. In the older portions of the root these vesicles are seen to disintegrate and free their contents in the cortex, as has been described by MacDougal in *Corallorhiza*†

The nuclei of the cells inhabited by the fungus show a varied behavior. In some instances they are double the normal size, very granular, and hyperchromatic. The shape in such instances varies from spherical to oblong ovoid. In roots examined early in May the nuclei of the infected cells were irregular in outline, diminished in size, and in some instances had fragmented into two or three segments.

External to the region just described is a second, consisting of two layers of long cylindrical cells, with no intercellular spaces, and thickened at the angles. These cells contain active hyphae which form more or less dense convolutions at random, but which do not appear to influence the nucleus of the cell inhabited, as they are fairly normal in size and structure.

The Sheath.—The outer layer of the cortex consists of two kinds of cells; a long cylindrical form, and a short cylindrical form of smaller diameter. The longer cells are placed with their greater axes parallel to that of the root, and they alternate with the shorter ones which have their longest diameter radial. Any row of cells in this layer consists of the two kinds of cells placed alternately, so that each long cell is separated from the end of the one above it by a short one. The diameter of the short ones is less than that of the long ones, and as a consequence, the edges of the long ones may be prolonged to meet at the sides of the short ones, a fact that may be seen in tangential sections only.

The outer and inner walls of the smaller cells of this layer are noticeably thinner than the later ones and this device allows the ready passage of the hyphae, which crowd through these passage cells so densely as to almost fill the cavities. (Pl. 372. f. 4.)

Epidermal Tissue.—External to the sheath is a tissue consisting of four or five layers of thin-walled cells, rich in protoplasm, with no intercellular spaces. This layer is continuous over the apex of the root, on which no cap can be distinguished. It is suggested

† Symbiosis and Saprophytism, Bull. Torr. Bot. Club, Oct., 1899.

that this may be a true many-layered epidermis, developed for the especial needs of a mycorrhizal organ, similar to that described by Groom in *Thismia* (Annals of Botany, 1895). The outer wall of the external layer is extended in the form of root-hairs which are persistent, and which exhibit great diversity of shapes. Some of these organs are branched, while the apices of others are converted into hollow disks, or into the form of the pileus of a mushroom. These hairs are traversed by hyphae which pass through their lateral walls into the humous soil.

The cells of the epidermal tissue contain hyphae which pass towards the apex of the root in nearly straight lines. The hyphae give off short lateral branches which are enlarged, and are of the form of the sporophores of some of the moulds, though never seen to develop spores. These organs are cut off from the main hyphae by septae, and are sometimes to be seen separated from the hyphae, and may possibly serve as reproductive bodies. The hyphae are septate throughout all of the regions mentioned.

The hyphae which traverse the root-hairs sometimes form convolutions within them, and nearly all of the hairs thus inhabited show distortions as previously described.

In addition to the symbiotic fungus, the smaller hyphae of a second organism, probably parasitic may be seen in the roots of some specimens.

SUMMARY

The principal features of interest in the mycorrhiza of *Tipularia* consist in the lack of the root cap, the development of a many-layered epidermal tissue, which serves the immediate purpose of affording a habitat for the vegetative mycelium of the symbiotic fungus: the formation of a special sheath from the external layer of the cortex, certain cells of which are converted into passage-cells, through which the internal hyphae find an easy passage into the medio-cortex with its rich content of carbohydrates.

The general organization of the fungus, and its relation to the seed plant is similar to that described by MacDougal in *Corallo-rhiza* and other mycorrhizal forms.* The hyphae in the epidermal

* Symbiosis and Saprophytism, Bull. Torr. Bot. Club, Oct., 1899.

tissue constitute the vegetative mycelium, which sometimes forms branches which may be reproductive in their primary purpose. Branches are given off which traverse the root-hairs and penetrate the soil, constituting the absorbing organ of the mycorhiza, and which serve to bring the humous products within the root. Branches are given off which penetrate the cortex through the passage cells, forming vesicles which serve as organs of interchange. Starches and other carbohydrates are taken from the higher plant, and proteids are formed from these and the humous products brought in from the soil, which are finally liberated by the disintegration of the vesicles. The seed plant affords a habitat also to the fungus, so that a fairly well balanced symbiosis is the result.

Explanation of Plate 372

All drawings were made from a Bausch and Lomb one-fifth inch apochromatic objective, and a No. 4 compensating ocular. Magnification 159 except in figure.

FIG. 1. Cross section of stele. *x*, *x*, *x*, *x*, *x*, scalariform ducts. *s*, spiral vessels.

FIGS. 2 and 3. Root-hairs, showing form and traversing hyphae.

FIG. 4. Tangential view of outer cortical sheath, showing the long cylindrical sheath cells, alternating with the short passage-cells.

FIG. 5. Longitudinal section of cortex and epidermis. *c*, outer epidermal cells with root-hairs. *s*, sheath. *o*, region containing vegetative mycelium of fungus. *m*, medio-cortex. *h*, disintegrating vesicles. *n*, nucleus.